Thesis/
Reports
Daniel,
T. C.

ASSESSMENT OF PUBLIC PERCEPTIONS AND VALUES REGARDING MOUNTAIN PINE BEETLE AND WESTERN SPRUCE BUDWORM IMPACT IN THE COLORADO FRONT RANGE

Terry C. Daniel

Library

ASSESSMENT OF PUBLIC PERCEPTIONS AND VALUES REGARDING MOUNTAIN PINE BEETLE AND WESTERN SPRUCE BUDWORM IMPACT IN THE COLORADO FRONT RANGE

Final Report

Forest Insect and Disease Management

Eisenhower Consortium

16-930-GR

Submitted by:

Terry C. Daniel

Professor of Psychology and

Renewable Natural Resources

University of Arizona

Tucson, Arizona 85721

11/21/81

LIBRARY COPY
ROCKY MT. FOREST & RANGE
EXPERIMENT STATION

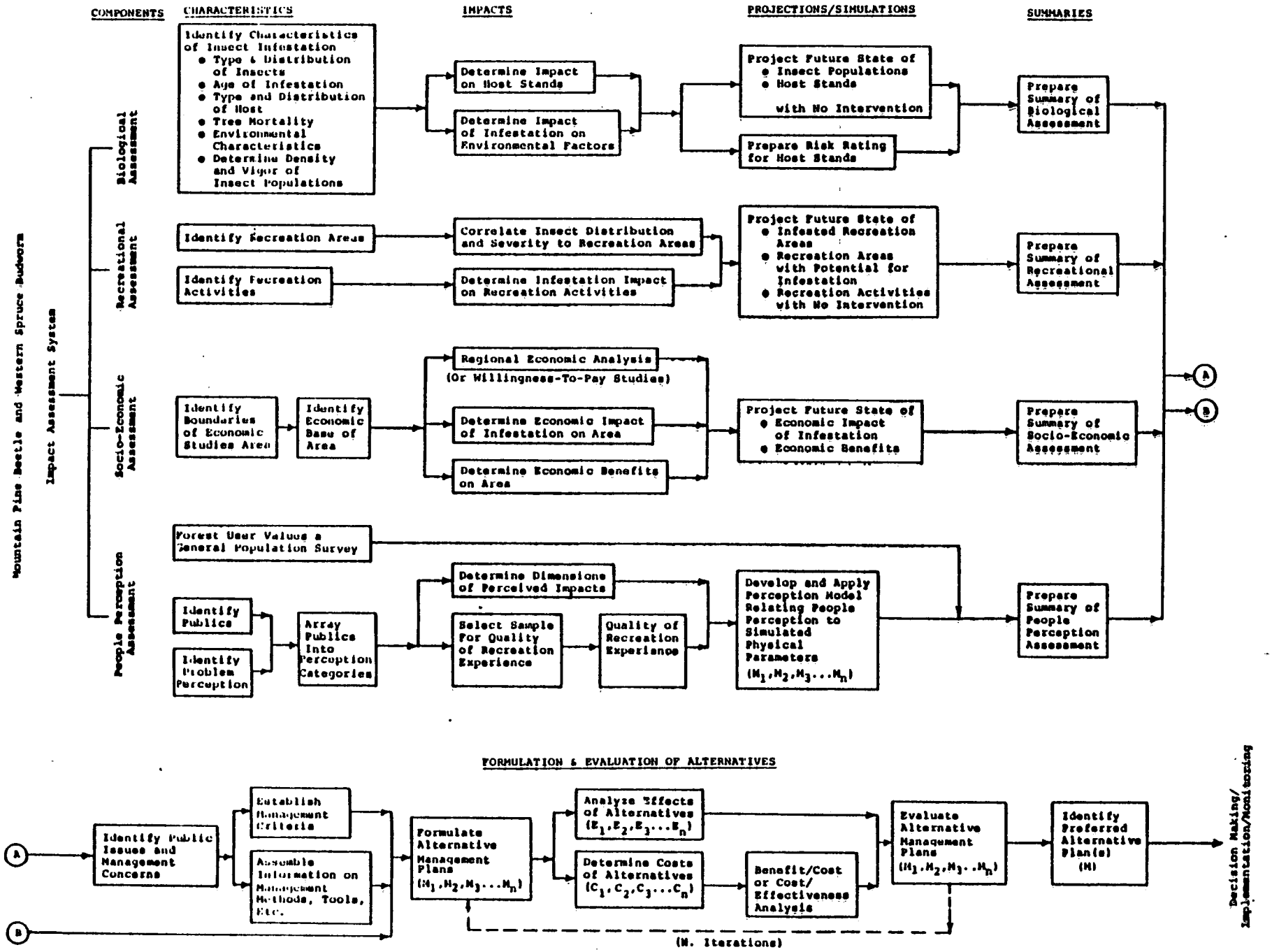
Assessment of Public Perceptions and Values Regarding Mountain Pine Beetle and Western Spruce Budworm Impacts in the Colorado Front Range

Infestations of mountain pine beetle (Dendractonus ponderosae) have historically impacted pine forests along the Colorado Front Range. The most recent epidemic of bark beetles began in the 1960s and reached its peak in the 1970s. Millions of trees were affected throughout the range, with mortality reaching levels in excess of 1 million trees per year at the peak of the epidemic. The cost of these losses can only partly be assessed in terms of the dollars in lumber resources represented. Front Range forests are not large producers of merchantable timber, but they are extremely important as a scenic setting for forest residential communities, for recreation and tourist activities, and as a visual backdrop for Colorado's major metropolitan areas. The short-term visual effects of large patches of dead pines with reddish-orange needles are in stark and ugly contrast to the green forested slopes to which visitors and residents have become accustomed. Long-term consequences of large scale losses of the larger pine trees preferred by beetles may be less dramatic, but can effect the scenic and recreation value of Front Range forests for generations.

In response to public concern, the US Forest Service, Colorado State Forest Service, and several county and municipal agencies have waged a cooperative attack on the mountain pine beetle. The approach taken has been termed "Integrated Pest Management," employing a battery of chemical, biological, and host oriented attacks on beetle populations. In this context, the Forest Insect and Disease Management staff initiated a program of research to develop an "Impact Assessment System" as a central component in Mountain pine beetle and Spruce Budworm Management Systems. (USFS, FI&DM, 1979).

The FIDM assessment system is shown graphically in Figure 1. It includes

Figure 1. MOUNTAIN PINE BEETLE AND WESTERN SPRUCE BUDWORM IMPACT ASSESSMENT SYSTEM


Mountain Pine Beetle and Western Spruce Budworm Impact Assessment System
COMPONENTS
CHARACTERISTICS
IMPACTS
PROJECTIONS/SIMULATIONS
SUMMARIES
Biological Assessment
Identify Characteristics of Insect Infestation
• Type & Distribution of Insects
• Age of Infestation
• Type and Distribution of Host
• Tree Mortality
• Environmental Characteristics
• Determine Density and Vigor of Insect Populations
Determine Impact on Host Stands
Determine Impact of Infestation on Environmental Factors
Project Future State of
• Insect Populations
• Host Stands
with No Intervention
Prepare Risk Rating for Host Stands
Prepare Summary of Biological Assessment
Recreational Assessment
Identify Recreation Areas
Identify Recreation Activities
Correlate Insect Distribution and Severity to Recreation Areas
Determine Infestation Impact on Recreation Activities
Project Future State of
• Infested Recreation Areas
• Recreation Areas with Potential for Infestation
• Recreation Activities with No Intervention
Prepare Summary of Recreational Assessment
Socio-Economic Assessment
Identify Boundaries of Economic Studies Area
Identify Economic Base of Area
Regional Economic Analysis
(Or Willingness-To-Pay Studies)
Determine Economic Impact of Infestation on Area
Determine Economic Benefits on Area
Project Future State of
• Economic Impact of Infestation
• Economic Benefits
Prepare Summary of Socio-Economic Assessment
People Perception Assessment
Forest User Values & General Population Survey
Identify Publics
Identify Problem Perception
Array Publics Into Perception Categories
Determine Dimensions of Perceived Impacts
Select Sample For Quality of Recreation Experience
Quality of Recreation Experience
Develop and Apply Perception Model Relating People Perception to Simulated Physical Parameters
$(M_1, M_2, M_3 \ldots M_n)$
Prepare Summary of People Perception Assessment
A
B

four assessment components; Biological, Recreational, Socio-Economic, and People Perception. The research presented in this report was conducted in the context of developing the People Perception assessment component. Included in this part of the assessment system are "near-view" and "vista" Scenic Beauty Estimation models, and a general assessment of scenic impacts of mountain pine beetle and western spruce budworm damage to the Colorado Front Range. The Near-View model provides estimates of the effect of tree damage and mortality on forest views that are typical for hikers, campers, and other recreators or visitors within the forest. The Vista model estimates effects on more distant views, such as those from major roads, developments, or scenic overlooks. In combination, these models provide a means for estimating the scenic/esthetic consequences of insect infestations and alternative forest management actions that might be implemented in response to such infestations.

Background

Esthetic impacts of all management actions on forest lands must be assessed and carefully considered. The National Environmental Policy Act of 1969 established a national goal to maintain and enhance environmental quality. Under this act federal agencies are directed "to identify and develop methods and procedures...which will ensure that presently unquantified environmental amenities and values may be given appropriate consideration in decision-making along with economic and technical considerations" (42 U.S.C. § 4321 et. seq.). Likewise, the Multiple Use Sustained Yield Act of 1960 requires that national forests be managed with concern for intangible products (esthetics, wildlife, and recreation) as well as tangible ones. The mandates of these laws have been reinforced and extended by more recent acts, specifically by the Forest and Rangelands Renewable Resources Planning Act (1974) and the Forest Management Act (1976).

These congressionally enacted policies become operational when a forest manager must decide whether to institute, expand, or modify a management program resulting in esthetic impacts. Forest insect and disease control decisions may have esthetic impacts particularly if an outbreak occurs near intensively used recreation areas or corridors. Presently the forest manager is offered no specific guidelines or procedures for determining levels of insect-caused impacts to esthetic resources, nor are means available for evaluating the esthetic consequences of alternative insect control strategies that might be implemented. As a result, individual planners and managers are left largely to their own devices to determine when impacts are sufficient to require action, and what actions should be taken to successfully mitigate impacts.

The quantification of scenic beauty and/or scenic preference is a prerequisite to determining esthetic consequences of management actions. Methods used to assess and predict esthetic values must meet certain standards to be useful in forest pest management and decision-making: First, scenic beauty and/or scenic preference measures must be reliable and valid. Second, environmental conditions (e.g., the effects of insect infestation and/or management actions) causing scenic beauty or preference fluctuations must be identified. Finally, predictive models should be empirically valid and useful.

Few systematic studies have focused on these problems and even fewer have attempted to deal with them simultaneously. For example, a model developed by Shafer and others (1969) used areal and perimeter measurements of landscape zones (taken from photographs) to predict esthetic appeal. However, because the intent of the model was prediction and not explanation, the mathematical complexity of some of the combinatory variables defied even conceptual cause-effect explanation. Also, their model's dependent variable (visual preference) was only an ordinal (rank) value. Thus, this model was unable to specify magnitudes of scenic beauty or preference changes as the result of physical changes

in the environment.

Some researchers have developed measurement and modeling systems which substantially meet the standards cited earlier. For example, interest in the measurement of magnitudes of preference and scenic beauty led Daniel and Boster (1976) to develop a Signal Detection Theory based method whereby Scenic Beauty Estimates (SBE's) could be computed for landscapes. This method has been successfully used to gauge the effects of silvicultural treatments (Daniel, et al., 1973; Schweitzer, et al., 1976), to develop a mapping procedure for scenic beauty in forested landscapes (Daniel, et al., 1977), and to develop models of landscape assessment using mensurational parameters as predictors (Arthur, 1977; Daniel & Schroeder, 1979; Schroeder & Daniel, 1981). Other attempts at measuring interval preferences also rest on the foundations of psychophysical scaling methods similar to Signal Detection Theory. Jackson et al. (1978) used the Law of Comparative Judgment and the Luce Axiom to obtain estimates of visual impacts of power-line corridors. Buhyoff and Riesenman (1979) also demonstrated that psychophysical scaling can provide reliable estimates of the magnitudes of visual preference.

In an effort to estimate the esthetic impacts of southern pine beetle (SPB) damage, Buhyoff and Leuschner (1978) measured magnitudes of preference for forest landscape scenes with a variety of types and levels of SPB damage. Preference was measured using the Case III assumptions of the Law of Comparative Judgment (Guilford 1954:155). This methodological procedure produced interval preference scores for landscapes which were then correlated with changes in SPB damage. Non-linear estimation techniques produced an empirical two-dimensional psychological disutility function for people who knew they were viewing southern pine beetle (SPB) damage (Buhyoff and Leuschner, 1978). Experimental data collection techniques permitted "forced" subject cueing on a

single dimension thereby producing linearized logarithmic functions which accounted for approximately 0.86 of the variability in landscape preference scores. Lower amounts of variability in preference ($R^2 \simeq 0.33$) were accounted for when people did not cue on a single dimension. Thus, magnitude estimates of preference can be made for an overall landscape scene and measures of physical landscape elements can be used in models to predict these preference changes.

Objectives

The overall objective of the current assessment was to evaluate the impact of Mountain Pine Beetle (MPB) and Western Spruce Budworm (WSB) on perceived scenic and esthetic values in the Colorado Front Range and to develop a general operational system for predicting the scenic and esthetic consequences of alternative insect management approaches. In order to achieve this objective, it was necessary to:

1. Identify publics concerned or affected by MPB and WSB infestation and management impacts and define the dimensions (e.g., scenic beauty, "naturalness," economic/property values, hazards) and contexts in which those impacts are perceived.
2. Quantitatively assess the perceived quality (scenic beauty, landscape preference, and other values as indicated by 1 above) of sample sites based upon the judgments of identified public groups.
3. Extend existing quantitative psychophysical models to relate insect damage and associated forest characteristics to perceived environmental quality and utility values.
4. Develop and test a preliminary package to assist in evaluating the esthetic effects of alternative insect management strategies.

Objective 1: Public Concern

To identify the dimensions of the public's perception of insect impacts in the Front Range, several approaches were taken. First, newspapers and other publications carrying articles, letters, and reports regarding the problem were sampled and reviewed. U.S. Forest Service environmental impact reports, planning documents, and public involvement reports were studied as sources of information about public perception of insect and insect management effects. Direct discussions with U.S. and State Forest Service personnel in the Front Range were also an important part of the preliminary public perception analysis.

As one approach to ascertaining the public's awareness and interpretation of the insect infestation problem in the Front Range, newspaper clippings from the area were surveyed. The source of clipping samples was the file maintained by FI & DM in the Regional Office in Lakewood, Colorado. This file contains articles clipped by forest service personnel throughout the Region that reference insect or disease problems or related management activities. The contents of the file are selective, not comprehensive, and they do not represent a consistent or complete sample of publications. Still, the contents of this file can give a general indication of the level and nature of public concern and information in the region.

Clipping files were surveyed in 1978, 1979, 1980, and 1981. The number of clippings in the file varied considerably, reflecting both the effects of waning public interest in the pine beetle, and perhaps associated changes in Forest Service procedures for maintaining the file. Table 1 reveals that there were 127 articles in the 1978 sample that included reference to mountain pine beetle. By 1981 the number had dwindled to 5 articles. At the same time, articles referencing other insect pests, including western spruce budworm,

Table 1

Sources of sampled clippings and numbers of articles referencing different insect pests for the years of the study.

Sources	Number of Articles		
	Year	MPB	SBW	Other
Denver Post	1978	127	10	1
Rocky Mountain News	1979	12	0	2
Montezuma Valley Journal	1980	8	5	2
Pagosa Sun	1981	5	1	8
Boulder Daily Camera				
Glenwood Post				
Montrose Daily Press				
Boomerang (Wyo.)				
Coper Star-Tribune (Wyo.)				
Pueblo Star-Journal Chieftan				
Town & Country Review				
Longmont Daily Times-Call				

tussock moth, tip moth, gypsy moth, grasshoppers and elmbark beetle, occurred with increasing frequency in the sample of clippings. While the sampling strategy and the changes in clipping file maintenance procedures over these years make detailed comparisons inappropriate, the general evidence of decreasing public attention to and concern about mountain pine beetle seems substantial.

Table 2 presents some selected titles and quotations from newspaper articles over the period of the study. These help to indicate the nature of public concern, and provide some impressions of the "intensity" of concern. Clearly there was considerable concern in 1978 that pine beetles might denude the entire front range. In 1979, the theme of many articles was that control programs were working and that the public should lend their support. By 1980, the pine beetle problem was viewed as largely subsided, and in 1981 a Casper, Wyoming article referred to the Front Range pine beetle problem as a historical event from which important lessons were learned. The theme of articles in Colorado shifted to concern about spruce budworm impacts, especially on damage to christmas trees. All indications were that other forest pests were of more concern than mountain pine beetles in 1981.

The motivations for public concern about the mountain pine beetle epidemic were not clearly articulated in the newspaper articles sampled. Many articles focus upon the gravity of the problem and the importance of "controlling the pine beetle." Certainly the death of trees was of great concern, but it is less clear why tree losses were viewed as important. Other evidence indicates that commercial uses of Front Range Forests are relatively minor. Fuel wood does appear frequently as a concern, especially focussing upon availability for local individuals. The pine beetle, in one sense, was a boon to fuel wood supplies, and beetle declines may actually create shortages of dead wood available for fuel purposes. While rarely explicit, an underlying theme for concerns seemed to be esthetic -- a concern for preservation of the character of Colorado

and for the scenic value of the Front Range Forests. These forests provide scenic backdrops for cities such as Denver, Colorado Springs, and Boulder and a context for tourist and outdoor recreation activities. There were frequent references to the visual consequences of pine beetle damage, the reddish-orange patches on forested hillsides, the standing dead trees, and the forest stands converted to "meadows."

Based on reviews of clipping files, letters submitted in the context of environmental impact statement and public involvement procedures, discussions with Federal, State, and local Forest Service personnel, and informal interviews with residents, tourists, and resort operators in the Front Range, it was concluded that visual esthetic impacts motivated a large share of public concern about mountain pine beetle. Although many other factors were found to be important -- commercial forest products, fuel wood, forest fire danger, wildlife habitat -- natural scenic beauty appeared to be of greatest concern to the largest share of the affected public. Thus, the people perception assessment focussed upon systematic evaluation and modeling of the effects of MPB, and to a much lesser extent WSB, on scenic values in the Front Range.

Table 2

Selected Excerpts from Sampled Articles

1978

"Boulder residents have been dismayed to see nearby mountains turn brown over the past several years--the result of the pine beetle's appetite for pine." (Town & Country Review, April 26)

Official: Beetle epidemic may wipeout forests.

"Unless the beetle epidemic is reversed, ...Front Range forests will be wiped out, imperiling wildlife, mostly birds, dependant on tree cover, while robbing the state of much of its natural beauty." (Longmont Daily-Times Call July 17)

"The mountain pine beetle is moving faster than the forest crews and threatens to destroy the trees of Boulder's mountain backdrop within five years." (The Denver Post, November 25)

1979

"The battle to control the pine beetle epidemic west of Boulder is an example of a federally-financed program that works...In addition to cutting infected trees and chemically treating the wood to kill the beetles, workers also clear the forest, removing some of the densely packed trees so the remaining trees will be able to grow faster and stronger and become more resistant to the beetle. (Boulder Daily Camera, February 4)

"The bad news is that beetles already have killed about 1.5 million to 2 million pine trees in Colorado this year. The good news is that steady progress is being made to control the problem.

On the other hand, the beetles are killing a lot of trees. On the other hand, though, they are getting rid of the weaker trees. In a way, the beetles are doing our job for us." (The Denver Post, June 17)

1980

Swan song of the pine beetle

"After more than a decade of feasting in our forests, the pesky bug has eaten itself out of bed and board." (The Denver Post, October 12)

1981

"Casper Mountain (Wyoming) is one of the state forestry division's high priority areas for control of Mountain Pine beetle infestation...group has a better chance of licking the problem now compared with the infestation on the Front Range in Colorado where acres of trees were lost... (Casper Star-Tribune, April 2)

"Foresters gird for battle against killer caterpillar (tussock moth)." (Rocky Mountain News, April 19)

Objective 2: Scenic Impact Assessment

The purpose of this component of the project was to obtain a general assessment of the scenic values in the Colorado Front Range. The sample area included the entire Front Range from the Wyoming border in the north to the New Mexico border in the south (see map in Figure 2). "Random Sampling" of so large an area was clearly infeasable, thus, emphasis was placed upon sampling areas having high public visibility, including roads, recreation sites, hiking trails, and seasonal residential developments. In each case, views were represented by color-slide sampling procedures that simulated views that would typically be experienced by visitors to these areas. Views included both within-the-forest perspectives and distant panorama or "vista" perspectives. Forest conditions ranged from open mature ponderosa stands to dense lodgepole thickets. Insect impacts ranged from undetectable to devastating.

Color-slide samples were catalogued and referenced to their respective ground locations. Scenic beauty values were obtained by submitting slides to panels of observers who rated their scenic beauty using procedures described by Daniel and Boster (1976). Calculated "Scenic Beauty Estimates" were then used to assess variations in scenic value throughout the Front Range. The relationship between scenic beauty and mountain pine beetle damage was generally determined by mapping scenic values against FIDM maps of insect damage for the same areas and time periods. More detailed assessment of the relationship between pine beetle damage and forest scenic beauty is presented in the prediction model sections of this report.

Assessment: Road Samples

Road segments to be included in this sample were selected after consultation with U.S. and Colorado State Forest Service personnel throughout the Front Range. Areas of high scenic importance, such as major recreation traffic

corridors, were emphasized. Consistent with the major focus of this assessment effort, areas potentially susceptible to MPB and/or WSB were primarily targeted.

The map in Figure 2 shows the locations of the 45 separate road samples that were photographed in the summers of 1979 and 1980. Each road (road segment) was divided into equidistant sample points ranging from .10 miles to 1.0 miles between points, depending upon the length and usual speed of travel for the road. In all, 715 sample points were established. At each point four color slides were taken, two on each side of the road. Slides were oriented at approximately 45° to the road alignment, one forward and one rearward on each side of the road. This procedure yielded a total of 2,860 color slides, each cataloged as to its road and sample point location.

A few slides were rejected due to poor photographic quality. Many of the slides included features such as houses, other roads, fences, telephone poles and lines, and signs, which are unavoidable along roadways in the Front Range. Composition of landscape scenes depicted ranged from bare road cuts and dense pole stands to expansive green meadows and valleys with snowcapped peaks in the background.

Many more slides were available than was practical (or necessary) to present for evaluation by observer panels. To reduce the sample, two slides were randomly selected from each point along the sampled roads. Some points were excluded because of unacceptable slide quality or unusually distracting artifactual features (large signs, bridges, etc.). For longer roads, with more than 20 sample points, only every other point was sampled. In all, 994 slides were judged using the 10-point scenic beauty rating scale procedure. Over 300 observers (mostly university student volunteers) in 10 separate panels were involved in this phase of the study. Observers were instructed that all slides depicted views from along roads in the Colorado Front Range. Slides from all roads were randomly interspersed, along with a 25-slide "baseline" set (selected

from slides of ponderosa pine forests in Arizona, and used as an anchor or zero slide set in many studies since 1976).

Inter-panel correlations for ratings of the common baselines ranged from .71 to .92. There was no effort to preserve sequence or contiguity of roads or sample points; a procedure indicated by studies conducted earlier (Schroeder and Daniel, 1980). Observers were asked to judge the scenic beauty of the area represented by each slide independently.

The scenic value of a road may be characterized in several ways. The overall value of one road may be compared to that for another road. For this purpose the average scenic value (arithmetic mean of SBEs for all photos) may be calculated for each road of interest. In the current sample, based on two slides per point for slightly less than all of the points on each road, mean SBEs range from -21 to 129, with a mean value of 76. That is, Front Range roads averaged 76 SBE units higher than the 25 Northern Arizona baseline slides. This is not surprising as the baselines were all close-up views, while road photos were often of mid-range or distant vistas. Of course, the variation in scenic values from one view to another along a road can be large. In the present reduced sample, standard deviations (of SBEs) ranged from 23 to 61, with a mean of 41. Means and standard deviations for all roads sampled (based on reduced slide-sets indicated) are shown in Table 3.

The point-to-point variation in SBEs along a road can be represented by a Scenic Beauty Profile (Schroeder and Daniel, 1980). The profile for Colorado Route 67, Woodland Park to South Platte is presented in Figure 3 for illustration. Notice that the magnitude and sequence of SBEs, from either end of the road, is readily apparent in this graphic. Points of interest, e.g., those having very high or very low SBEs, may be investigated by referring to the

Table 3

Means and Standard Deviations of SBEs for
Colorado Front Range Road Sample

Road Description	No.Slides	Mean SBE	S.D.
1979			
Route 67, Woodland Park to Oxyoke, Route 97, Oxyoke to South Platte	(60)	96	53
Rocky Mountain National Park, Deer Mountain to Moraine Park	(40)	113	53
Bear Lake Road, Rocky Mountain National Park	(30)	68	45
Route 7, Allens Park to Estes Park	(34)	77	49
Route 36, Estes Park to Lyons	(20)	73	47
Route 126, Top of World to Wigwam	(34)	76	46
Rampart Range Road, Woodland Park turnoff to Indian Creek	(64)	65	26
Red Feather Road	(18)	72	37
Route 14 to Stove Prairie	(16)	85	35
Route 24	(16)	75	24
Lost Park Road	(18)	62	47
Route 285	(6)	84	42
Jefferson Lake Road	(16)	49	23
Route 306	(26)	83	45
Route 96	(12)	74	36
Colorado Route 72	(24)	83	38
Colorado Route 119	(38)	63	48
Pueblo Mountain Park Road	(18)	86	29
Boulder Canyon Road	(16)	95	32
Colorado Route 36	(6)	-21.0	45
Route 34	(18)	88	36

Table 3 (cont'd)

Road Description	No. Slides	Mean SBE	S.D.
U.S. 40 to I-70	(24)	68	51
Route 285, Baily to Conifer	(14)	57	30
Mount Evans Management Area	(22)	87	45
Route 165	(26)	102	31
Dillon Valley Road	(4)	28	29
Dillon Reservoir Road	(26)	72	52
F. S. 243	(12)	40	33
Route 6	(22)	75	40
Weston Pass Road	(14)	69	39
Colorado Route 9	(20)	101	52
Leadville to Buena Vista	(14)	57	41
Route 285, Evergreen to Conifer	(16)	93	54
Cottonwood Pass Road	(22)	60	32
F. S. 120	(18)	101	41
Lake Isabel Road	(14)	90	31
F. S. 400, San Isabel	(16)	97	40
Dillon Peninsula	(16)	46	61
1980			
F. S. 306, San Isabel (partial resample)	(32)	98	38
Colfax Road and Route 69	(12)	129	40
Tarryall Road	(14)	35	36
Route 67 (partial resample)	(40)	74	44
Lake Isabel Road (partial resample)	(16)	87	43
Deer Ridge Moraine, Rocky Mountain National Park	(28)	95	60
Bear Lake Road (partial resample)	(22)	91	38
TOTAL/MEANS	(994)	74	41

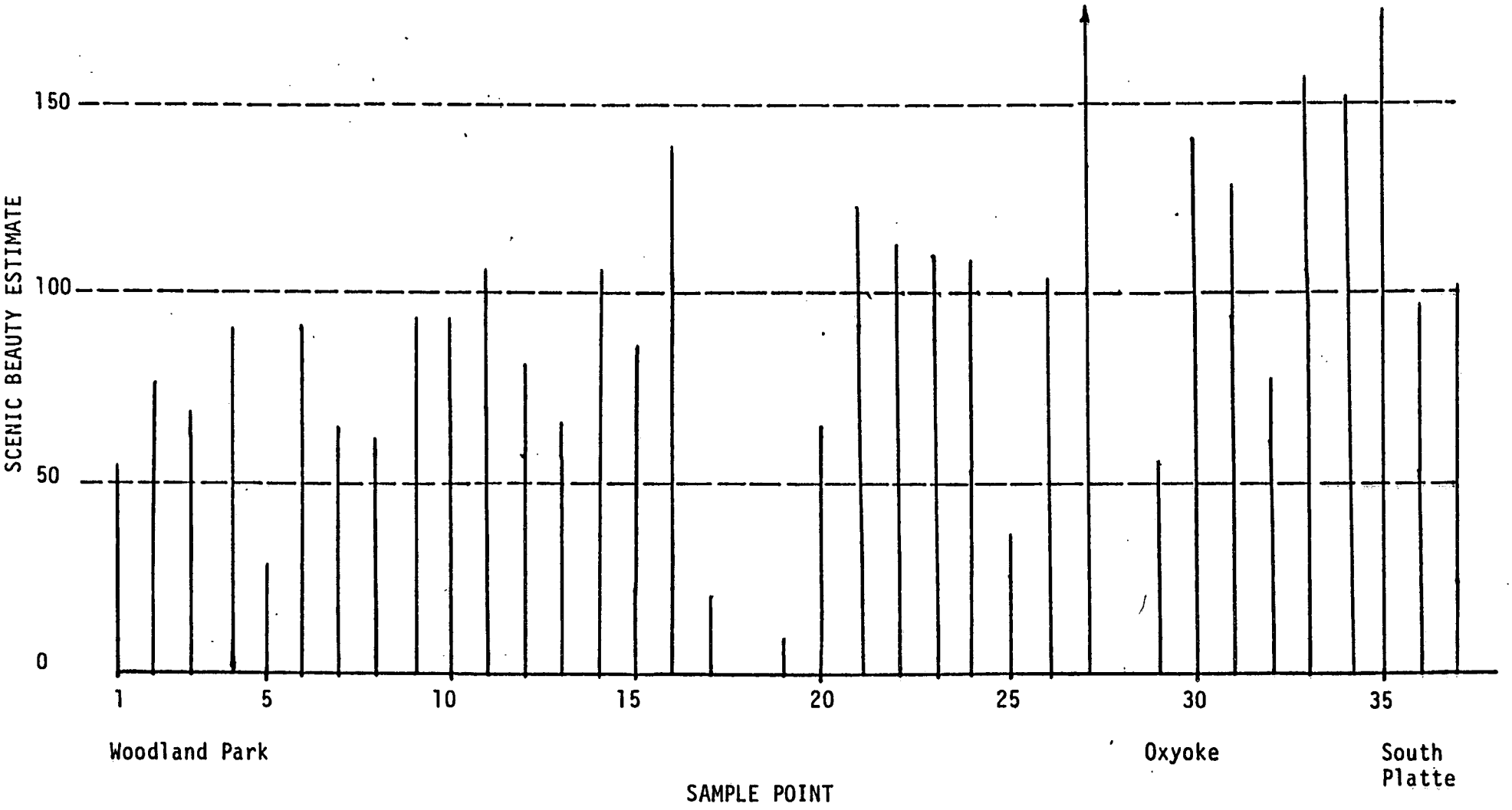


Figure 3. Scenic Beauty Profile for Route 67 Woodland Park to Oxyoke, and Route 97 Oxyoke to South Platte

appropriate set of slides (two at each point in this case) or by actual field visits to the approximate location where the slides were taken.

A disadvantage of the profile procedure as applied here is that differences in scenic values between different views at a given sample point are not revealed. Only the mean value for each point is shown. Thus, if one view at a point were very high in scenic value, and another view were very low, the point would be represented by a medium value. Further, the simple averaging scheme does not take into account the amount of area represented by a given view. A view covering only a few feet of dense lodgepole pines will weigh equally with a view depicting a vast vista in determining the average SBE value for a point on a road.

Daniel, et al. (1977) and Schroeder and Daniel (1980) found that, in spite of a priori intuitions to the contrary, simple means provided the best overall measure of the scenic value of a point offering multiple views in a ponderosa pine forest. In both of these studies, however, the forest was rather homogeneous and there were no major land form variations. In the Front Range road sample, on the other hand, there is considerable variation in the composition of views from a given point. Thus, other methods of deriving values for each point along a road, based on two to four slides per point, should be investigated in the future. Perhaps some distance or area weighted average would provide a more valid measure.

An analysis of the composition of road-sample slides revealed that major land forms and major vegetation features were the most important determiners of scenic value. Consistent with the Vista Model findings reported in the following section, vistas showing snowcapped mountain peaks behind green grassy meadows and rolling green forested hills account for the highest scenic beauty values. Close-up views of dense forest stands were generally rated very low in scenic value. Specific features, such as lakes or streams, aspen stands, or

rock outcrops generally elevated scenic values, while road signs, cut banks, snow fences, and telephone lines and poles generally reduced values. Houses or cabins (of moderate to high value), cultivated fields, and livestock appeared to have either no effect, or a modest positive effect on scenic beauty judgments.

Visible evidence of insect damage was thinly scattered throughout the road sample photos. Where damage was visible, its effects on scenic values were varied, depending upon the gross land form of the scene and the location, amount, and type of damage present. Based on the judgments of uninformed observers (not instructed about MPB or its effects on forests), the brown-orange stage of damage produced the largest negative effects. Negative effects were greatest when groups of brown-orange trees were located in the mid-ground (approximately .25 to 1.0 miles from the viewer) of a moderately expansive vista. Effects were less noticeable if the vista was very expansive, especially if the view was back-dropped by snowcapped mountains. Apparently in such vistas, mid-ground vegetation features of any kind are somewhat overlooked by viewers who focus upon the larger features of the scene. Both brown-orange and gray-black (needles dropped) damage had negative effects when they occurred in the foreground of close-up or moderate range views. This is consistent with the pattern discovered in the Near View Models presented in the next section.

Insect damage does have a negative esthetic impact on the view from the road. The scenic impact of MPB must, however, be viewed as small relative to the effects of larger land form and vegetation features. When brown-orange damage is visible in the foreground or mid-ground of a primarily forested vista, scenic values will be lower than for a similar scene with no evidence of insect damage. Very distant MPB damage, or small amounts of damage (a few scattered trees)

in a large vista does not appear to have an appreciable effect on perceived scenic value.

Assessment: Recreation Sites

The sample of recreation sites included developed campgrounds and picnic grounds designated on forest maps for the Front Range. A total of 114 sites were sampled from throughout the area (see Figure 2). At each site approximately 8 randomly oriented photos were taken, each from a different location within the site. Because of differences in the size of the various facilities sampled, some were represented by as few as 4 photos or as many as 30. Photo sample locations were generally determined by the number and distribution of tables and/or fire pits at the site. All color-slide photo samples were catalogued, labeled and filed with reference to the ground locations of sites represented. A total of 940 color-slides were collected for this aspect of the scenic assessment.

As for the road assessment, the number of slides available was deemed greater than necessary or feasable given the scope and resources of the study. Thus, the sample was reduced by random selection of approximately half of the available color slides from each recreation site. The resulting photo sample and the mean SBEs and standard durations for each recreation site are shown in Table 4. Baseline correlations for five observer panels ranged from .82 to .92.

The range of scenic values for recreation sites was quite large, extending from low mean SBE of 16 to an impressive high of 192. The average SBE for recreation sites was 84, only 8 points higher than the average for the road samples. However, individual recreation sites did achieve higher values, 13 sites had average SBEs greater than 120; while only one road achieved a value this high. Of course, recreation sites may have been specifically selected for their scenic beauty, and they were typically high priority targets for pest management efforts; the fact it was very rare that any visible pine beetle damage was found in recreation sites.

Table 4

Average SBEs and Standard Deviations for
Front Range Recreation Sites*

Site	Mean SBE	Std. Deviation
1979		
Glacier Basin C.G.	16	36
Morraine Park C.G.	114	50
Shingle Mill P.G.	81	18
Blady P.G.	62	71
Buffalo Creek C.G.	81	33
Top of the World C.G.	59	44
North Creek P.G.	74	19
North Creek C.G.	97	18
South Creek P.G.	83	41
South Meadow C.G.	82	35
Colorado C.G.	78	17
Lone Rock C.G.	71	19
Kelsey C.G.	65	37
Recreation Site-Inside	78	16
Indian Creek C.G.	107	20
Flat Rocks C.G.	78	22
Cabin Ridge P.G.	55	16
Devil's Head C.G.	72	24
Jackson Creek C.G.	102	27
Ansel Watrons C.G. (2)	57	12
Diamond Rock (2)	42	42
Poudre Park	77	16
Poudre River #7 (2)	100	33
Springdale C.G.	84	35
Poudre River #2 (2)	72	70
Kelly Flats	66	16
Mt. Park	107	27
Poudre River #5 (2)	73	95
Poudre River #6 (2)	67	71
Poudre River #7 (2)	54	70
Poudre River #8 (2)	78	18
Platte River P.G.	76	13

Table 4 (cont'd)

Site	Mean SBE	Std. Deviation
Robber's Roost C.G. (3)	118	34
Floral Park P.G. (2)	134	49
Meeker Park P.G. (0)	**	**
Excelsior C.G.	77	45
Echo Lake C.G. (3)	42	17
Camp Rock C.G. (5)	81	48
Hayden Creek C.G.	122	44
Peak #1 C.G. at Dillon Reservoir (8)	51	36
Prospector C.G.	32	24
Eagle's Aerie P.G.	82	29
Arapahoe Springs P.G.	102	24
Cloudland C.G.	74	53
Byars Creek C.G. (2)	92	34
Red Rocks C.G.	58	12
Collegiate Peaks C.G.	93	32
Round Mountain C.G. (0)	**	**
O'Haver Lake C.G.	122	64
Cotton Wood Lake P.G.	120	64
Weston Pass C.G.	81	26
Ophir Creek C.G.	98	17
Baby Doe C.G.	79	63
Boulder Creek P.G.	93	29
Red Rocks C.G. (second sample) (0)	**	**
Molly Brown C.G.	35	38
1980		
Smith Creek P.G.	131	41
Rainbow Lake C.G.	99	30
Spring Creek P.G.	106	28
Cuchara C.G.	132	11
Davenport P.G.	141	7
Florence P.G.	91	36
Alvarado C.G. (resample)	103	45
Rainbow Lake lake sample	165	53
Buckingham C.G.	122	33
Kelley Dahl C.G.	44	38

Table 4 (cont'd)

Site	Mean SBE	Std. Deviation
Scraggy View P.C.	56	55
Pipe Springs C.G.	97	43
Blue Mt. C.G.	67	13
Jefferson Boundary C.G. (3)	106	12
Lodgepole C.G.	69	44
Cove C.G.	124	49
O'Brien Gulch P.G.	91	61
Round Mountain C.G. (0)	**	**
Wye C.G.	89	25
Peter's Dome P.G.	95	16
Michigan Creek C.G.	64	32
Kenosha C.G.	79	17
Geneva Creek P.G.	54	17
Lost Park C.G.	110	58
Aspen C.G.	82	11
Riverside C.G.	89	17
Springer Gulch C.G. (0)	**	**
Wagon Tongue C.G.	68	25
Eleven Mile P.G.	84	43
Running Bear C.G.	53	53
Spruce Grove C.G.	106	26
Duck Creek P.G.	42	38
Twin Eagles P.G.	30	12
Jefferson Creek C.G. (2)	75	38
11 Mile Res. State C.G.	75	27
Reservoir C.G.	123	51
Bailey P.G.	75	29
Deer Creek C.G.	82	48
Brainard Lake C.G. (8)	113	54
Painted Rocks C.G. (3)	82	44
Trail Creek C.G.	42	26
Wildhorn C. G.	43	35
Alvarado C. G. (0)	**	**
Lake Creek C.G.	51	52
Squaw Pass P.G. (3)	112	21
Jefferson Creek C.G. (0)	**	**

Assessment: Hiking Trails

A total of 26 designated hiking trails were included in the Front Range assessment sample. Each trail was photo sampled using a procedure similar to that used for roads. Sample points were established at equal walking time intervals. Intervals varied from 10 minutes for shorter trails to 30 minutes for longer trails. At each sample point six color slides were taken, two diagonally (45°) to each side of the trail, one forward along the trail and one to the rear along the trail. This procedure resulted in 956 slides representing views from points along the 26 Front Range trails indicated in Figure 2.

As for the other assessments, the photo sample was reduced by selecting four slides from each point at random for each trail. For trails having more than 6 sample points, approximately every other point was deleted from the sample. A few slides were rejected because of inadequate photographic quality.

The number of slides assessed for each trail is shown in Table 5. Mean SBEs and standard deviations are also presented. Average SBE values ranged from 13 to 98, with a mean for the 26 trails of 58 . Variability of values along a trail was comparable to that observed for roads and recreation sites, standard deviations ranged from 6 to 81, with a mean of 30. Baseline correlations for the 4 trail panels ranged from .72 to .86.

The composition of trail scenes tended to be near-view or within forest views, though some trails, especially in Rocky Mountain National Park, offered a substantial number of panoramic vistas. Trails with more vistas tended to have higher SBE values. MPB and WSB damage, when encountered, tended to reduce scenic values relative to similar scenes having no visible damage. The brown-orange stage of MPB damage had the most noticeable effect on scenic beauty judgements. These relationships are studied in detail in the Near View Model section of this report.

Table 4 (cont'd)

Site	Mean SBE	Std. Deviation
Springer Gulch C.G. (resample)	58	44
Jumbo Mountain P.G.	116	48
Colorado C.G.	90	35
Creedmore Lake C.G.	41	15
Lake Isabel P.G. (8)	84	34
Manitou Lake	175	21
Lake San Isabel Lake sample	192	17
Lory State Park P.G.	90	27
Bellaire Lake C.G.	55	14
Manitou Lake P.G.	107	95
Bellaire Lake lake sample	130	35
Lory State Park lake sample	68	24
Lake Isabel C.G.	50	29
Southside C.G.	22	10
Halloween P.G.	98	46
Aspenglen C.G.	98	17
Erdo Valley P.G.	118	30
Club Lake Trailhead P.G.	129	53
Halfway P.G.	21	37
Scraggy View P.G. (0)	**	**
Total Means (438 slides)	84	34

* All values based on 4 color-slide samples per site except where indicated.

** No values computed

Objective 4: Pest Management System

The Scenic Beauty Prediction models described in the preceding section were designed to form the basis of the "People Perception" component of the FIDM Integrated Pest Management System. Data about insect damage, forest overstory & understory, and general land form are combined to estimate public perception of the aesthetic quality of forest landscapes. These models were empirically validated against the esthetic judgments of hundreds of observers. They are statistically reliable and provide rather precise quantitative predictions of changes in public perceptual responses. Thus, given information regarding the physical biological variables required by the models, forest managers could have estimates of perceived scenic values for both near-view and vista vantage points in the forest.

To facilitate use of the quantitative prediction models, the linear equations (regression equations) for each were programmed for computer implementation. To use the models, then, the forest manager need only respond to queries from an easily understandable interactive program. For example, the user is asked

"Near-View or Vista vantage point?"

If the user replies

"Near-View,"

The next query is

"% Ponderosa Pine (80?, 40%, < 40%)."

The response to this query will determine which specific model will be used to predict scenic values.

Physical variable values for the site of interest are requested by a similar series of queries. For example,

"Number of Ponderosa pine 12" to 20" DBH per acre?"

When values for all variables have been entered, the equation is implemented and an SBE is provided. The user may then wish to modify some variables, such as increasing or decreasing the proportion of pines showing brown-orange damage, or reducing the number of large pines per acre, to determine the scenic consequences of a contemplated action. By iterations of this process, an acceptable set of management alternatives (regarding scenic beauty objectives) can be discovered.

More sophisticated systems could be developed by linking the Scenic Beauty Prediction models with "outbreak" type pest models or other forest growth and mortality models. This would allow rapid assessment of the scenic consequences of insect epidemics or of insect targeted management activities for designated times in the future (e.g., 5 yrs., 10 yrs., 50 yrs). Such a capability would undoubtedly benefit forest managers, but it may require greater sophistication than current quantitative models have been able to achieve. A simplified version of a computer assisted scenic impact prediction system is provided as an unattached appendix to this report.

Table 5

Average SBEs and Standard Deviations for
Hiking Trail Assessment Front Range

Site	#Slides	Mean SBE	Std. Deviation
1979			
Beaver Brook	15	47	14
Lost Creek Scenic Area Trail Sample	18	69	38
Boulder Canyon Park Ranger Trail	18	20	13
Mt. Elbert Rd. Trail Sample	16	57	20
Rainbow Trail N. of Balman Reservoir	10	60	32
Mitchell Lake & Blue Lake Trail	15	47	14
Rainbow Trail near Avadogn C.G. of Schoolfield Rd.	20	13	20
Rainbow Trail north of Music Pass	7	56	81
Natural Arch Trail	8	79	30
Second Mace Trail Sample	12	55	46
Natural Arches Trail Sample (second sample	23	62	34
1980			
Maintow Mountain Deception trail	11	73	12
Silver Circle Trail	12	90	34
Eagle's Nest Wilderness North 10 Mile trail	19	46	25
Rainbow Trail S. of Baldwin Reservoir	7	59	52
Woodland flat trail	17	77	30
Eagle's Nest Wilderness Boulder Creek Trail	16	70	31
Glacier Rim Trail	18	49	16
Meadow Creek Trail-Eagle's Nest	18	66	50
Lawn Lake	18	48	23
Mill Creek Trail	21	54	45
Aurthur's Rock - Long St. Park	18	40	44
Longs Peak Trail	16	35	16
Fern Lake Trail	17	75	22
Cub Lake Trail	8	51	6
Cub Lake Trail	12	98	21
Total/Means	390	58	30

Assessment: Homesites

A total of 10 different forest residential developments were sampled for the Front Range Scenic Assessment. The number of photo-sample points in each area was determined by size, development density and forest characteristics. Sample points were determined by intersections between private drives for individual homes and the principal through roads in the development. At each sampled intersection 4 color slides were taken, the first at a random compass heading and the rest at 90° increments from the first heading. No effort was made to avoid roads, buildings, or other development features as these were viewed as natural components of forest residential areas.

The number of slides taken in each of the 10 sampled sites is shown in Table 6. All of these slides were labeled and catalogued with regard to the sample point locations. The total 524 slides available were shown to panels of college student volunteers who rated each scene on a 10 point scale of scenic beauty. Observers were instructed that slides were taken in seasonal and permanent home developments in Colorado forests. They were asked to judge the "overall scenic attractiveness of the area represented by each slide as a location for a seasonal or permanent residence."

The standard set of northern Arizona baseline slides were interspersed among the homesite slides to establish between-panel agreement and as a basis for comparison of SBE values to those obtained in other assessment studies. Homesite slides were divided among 5 separate observer panels. A total of 149 observers rated the slides, with each slide being rated by at least 25 observers. Between panel agreement in SBEs was good, with baseline slide correlations ranging from .61 to .89.

Means and standard deviations of SBEs for each homesite sampled are shown in Table 6. Mean values ranged from -4 to 66, with an average value of 33. Within site variability was very high, standard deviations ranged from 32 to 53, with an average of 40.

Table 6

Means and Standard Deviations of SBEs
for Front Range Homesite Samples

Site	No. Slides	Mean SBE	S.D.
1979			
Sugar Loaf Mountain	(80)	43	49
Pine Drive	(32)	44	53
Big Elk Meadows	(104)	66	46
Payn Gulch	(32)	63	32
Hiwan Hills	(32)	-3	33
Silverthorne	(88)	22	40
Summit Cove	(28)	30	37
N.E. Woodland Park	(32)	38	33
1980			
Woodland Park	(32)	28	39
Red Feather	(32)	-4	37
Total/Means	(524)	33	40

The most noticeable feature of the homesite slides were the various human developments. Residential buildings were frequently visible in sampled scenes, and these ranged from "shacks" to "mansions." Styles for buildings also varied widely, including rustic log cabins, "swiss chalets," California ranch, A-frames, and modern wood and glass. Other development features included various out buildings, roads, parking areas, basketball courts, wood piles, and general clutter. Cars, trucks, and recreations vehicles were also occasionally seen. All of these features tended to reduce scenic values (relative to undisturbed forest scenes), but there was considerable variation in scenic effect depending upon the quality (cost?) and "fittingness" of structures and other development. Insect damage was rarely seen, though the effects of insect management were frequently evident, including stumps, slash piles, and stacked and sometimes covered "beetle wood." Without a detailed and extensive study, it is not possible to unravel the various scenic influences of all these interacting natural and man-made features displayed in the homesite slides.

Assessment: Conclusions

The results of the Front Range Scenic Assessment are summarized in Table 7. Over 2000 color slides representing views from roads, recreation sites, hiking trails, and residential areas throughout the Front Range were judged by over 600 observers. Views spanned a large spectrum, ranging from close-up views inside lodge-pole pine thickets to expansive vistas of the Colorado Rockies. Areas represented ranged from undisturbed forests to sites evidencing recent intensive management. Scenes included apparently primitive wilderness environments and intensively developed residential areas. In all of these contexts, MPB and WSB damage was relatively infrequent, but was occasionally a substantial and significant feature influencing scenic beauty judgments. In some situations, such as brown-orange damage in the midground of forested scenes, MPB damage had a substantial negative effect on scenic values. In scenes dominated by major

Table 7

Comparison of SBEs for Colorado Front Range Scenic Assessment Sample Sets

Sample	No. Samples	No. Slides	Mean SBE	S.D.
Roads	45	994	74	41
Recreation Sites	114	438	84	34
Trails	26	390	58	30
Homesites	10	524	33	40
Totals	195	2346		

geological features such as glaciated high sharp mountains, MPB damage was apparently "overpowered" by the stronger scenic features. WSB damage was less frequent, in part due to the emphasis placed upon MPB in these studies, and was generally much less conspicuous than MPB damage. When WSB damage was extensive in mid-range vistas of forested hillsides, scenic values appeared to be significantly reduced.

Inspection of the mean SBEs in Table 1 reveals that there were some differences in scenic value among the basic types of areas sampled. Recreation sites tended to have the highest scenic values, and residential areas had the lowest. While road, recreation site, and homesite samples all included some human development features, homesite slides contained by far the largest number and the most conspicuous development features. This may account for the frequently low values assigned to homesite samples (note that the baseline slides that were rated along with all of the assessment sample slides achieved the same mean value in each context).

Aside from development features, scene composition variables seemed to account for the largest share of scenic beauty differences. Generally, vista-type scenes were judged more attractive than within-forest scenes. Hiking trails had essentially no development features, but they also offered few expansive vistas; most views were of relatively close-in forest stands. As a consequence, the trail samples did not score as high as roads or recreation sites.

Roads had more vista scenes than did recreation sites, where in-forest views predominated, but recreation sites achieved higher SBE values. Two factors seemed to be involved. First, recreation sites tended to be located in open, mature forest stands with substantial ground covers. Sites were usually in valleys, relatively flat, and often included views of meadows and streams. Second, visible evidence of insect infestation was very rare in recreation sites, reflecting the priority these areas were assigned in the pest management efforts on the Forests. Where trees had been removed, care was taken to cut stumps close

to the ground and slash was completely removed. Also, recreation sites have presumably been systematically located in areas that are more scenically attractive.

Of course, all of these observations regarding the relationship of forest and development features to scenic values are tentative. They are based, for the most part, on informal inspection of high and low valued slides in each assessment sample. A more detailed and systematic analysis of the relationship between forest features, including insect damage, and scenic values requires the development of precise quantitative models. Such models were the focus of Objective 3 of the study and they are presented in the next section of this report.

Objective 3: Quantitative Models

Effective management of forest scenic resources requires that changes in the physical and biological features of the forest be systematically related to perceived scenic values. Forest managers must be able to determine in advance the scenic consequences of cutting trees, planting grass, or burning slash. In the context of Integrated Pest Management, it is important to know whether vegetative treatments will enhance or degrade scenic values relative to allowing insect infestations to run their course.

Early efforts to establish relationships between forest features and scenic values (e.g., Daniel & Boster, 1976; Shafer, et al., 1969) had a number of shortcomings (see Arthur, et al., 1977), but they did point out the need for and the possibility of developing quantitative scenic models. More recent efforts (e.g. Buhyoff & Leuschner, 1978; Buhyoff & Wellman, 1980; Buhyoff, et al., 1978, 1980), have applied more powerful methodologies to establish undimensional relationships between forest features (southern pine beetle damage) and judged landscape quality. These models evidenced substantial levels of quantitative precision and statistical reliability.

Following the lead of earlier research (Arthur, 1977; Daniel & Boster, 1976) multiple regression techniques were applied to develop quantitative prediction models for within forest views in ponderosa pine stands (Daniel & Schroeder, 1979; Schroeder & Daniel, 1981). These models attained substantial precision and reliability, and related field inventories of forest characteristics to quantitative measures of perceived scenic beauty.

Scenic beauty modeling efforts were extended in the present research. Multidimensional models were developed to predict the scenic consequences of MPB damage and insect-targeted vegetation management. Two families of

models were developed, Vista-Models related features measured from photographs of panoramic forest scenes to perceived scenic beauty. Near-View Models related typical forest mensuration measures collected in the field to perceived scenic beauty of scenes representive of views within the sampled forest sites. In each family of models, insect damage was targeted, and independent variables were restricted to "manageable features" about which most National Forests would be expected to have information.

Model Development: Scenic Vistas

Sixty-six vista sampling sites were selected for preference measurement from the photo sample drawn from throughout the Front Range during the summer of 1979. A panel of five judges viewed approximately 250 photo sample sites and selected the 66 photo sample. The final vista photo sites were selected based on three criteria.

1. The sites should represent the spectrum of scenic vista types which exist in the Front Range. This spectrum was based upon the dimensions of
   a. topographic variability
   b. vegetative variability
   c. insect damage variability with regard to stage and amount
   d. observer position with regard to the seen landscape
2. The sites should represent a "random" scatter from throughout (South/North) the Colorado Front Range.
3. Photographic quality should be good and either extremely spectacular or extremely poor photographs should not be used.

Selected photo sample points resulted in a random scatter from Rocky Mountain National Park to Walsenberg and from Denver to the Presidential Range.

A total of 669 observers participated in at least one of three procedures utilized to develop and test the convergent validity of a preference metric for the photo sites.

Two basic scaling approaches were used:

1. Scenic Beauty Estimation Method (SBE)
2. Law of Comparative Judgment (LCJ) utilizing both the full pair comparison and rank order methods on a random sample of 16 of the 66 sites.

Subject participation was as follows:

Law of Comparative Judgment (LCJ)

Psychology Subject Pool, Virginia Tech	= 148
Natural Resources Students, Virginia Tech	= 42
Psychology Subject Pool, Univ. of Arizona	= 96
Total	266

Scenic Beauty Estimation (SBE)

Psychology Subject Pool, Virginia Tech	= 119
Natural Resources Students, Virginia Tech	= 184
Church Group, Virginia	= 34
PTA Group, Virginia	= 66
Total	403
Grand Total	669

Some subjects participated in only one of the scaling approaches, others acted as observers for both. One group of 36 subjects were informed (experimental group) of the existence of insect damage before making their judgments. The remainder were considered to be naive.

Correlations were run between subject groups within a scaling approach and also between scaling approaches. The preference metrics for the Law of Comparative Judgement subject group correlated highly with one another (ranging from $r = 0.86$ to 0.95). It was also found that the SBE scores (metric) were highly intercorrelated for all groups who participated in this method (ranging from $r = 0.89$ to 0.97). Correlations between the metrics derived from both scaling

approaches for identical subjects ranged from r - 9.75 to 0.91. The correlation between a pooled SBE observer's metric and that of the experimental (informed) group of observers was 0.84. Two conclusions arose from this:

1. Regardless of subject origin or group identification, an identical landscape preference metric was obtained.
2. The high correlation between the landscape preference scores for identical photos and for identical subjects indicates that the two methods yield essentially the same metric, thus, a measure of high reliability is evident as well as convergent validity between the two scaling methods.

The sixty-six photographs were viewed repeatedly by a panel of judges in order to determine rational, intuitively pleasing and managerially relevant landscape zones to be measured. This process defined 93 different landscape zones and established corresponding definitions. These are given in Table 8. The distance zones (e.g., foreground, middle ground, background and very distant) were determined along a vegetation texture gradient. Trees and grass were the dominant vegetation used in this determination. For example, foreground trees are those for which needles are clearly visible; middle ground trees are those with boughs or branches discernable; background trees are those with crowns being distinguishable; and very distant trees are where crown separation is not distinct and are seen more as a common field of green. These vegetation identifiers were also used to categorize distance classes for the other landscape zones. By classifying the vegetation characteristics on a mountain side, for example, the distance class of the mountain was determined.

Three zones were then digitized in units of square inches for each photograph. From these 93 zones approximately 250 indices were formulated and set up as a 66 by 250 matrix to serve as candidate independent variables.

Regression model formulation based on the above potential independent variable matrix and the preference scores as the dependent variable vector.

Table 8

LANDSCAPE ZONE TAXONOMY AND DEFINITIONS

Taxonomy NO.	CODE	DESCRIPTION
1	ATB	above treeline, background
2	ATV	above treeline, very distant
3	CL	clouds
4	DB	dirt, background
5	DBB	blacktop, background
6	DBF	blacktop, foreground
7	DBM	blacktop, middle ground
8	DBV	blacktop, very distant
9	DEF	evidence, foreground
10	DEM	evidence, middle ground
11	DF	dirt, foreground
12	DM	dirt, middle ground
13	DRB	redtop, background
14	DRF	redtop, foreground
15	DRM	redtop, middle ground
16	DRV	redtop, very distant
17	GB	grass, background
18	GV	grass, very distant
19	MWB	moving water, background
20	MWF	moving water, foreground
21	MWM	moving water, middle ground
22	MWV	moving water, very distant
23	RB	rocks, background
24	RDAB	road, area measurement, background
25	RDAF	road, area measurement, foreground
26	RDAM	road, area measurement, middle ground
27	RDAV	road, area measurement, very distant
28	RDLB	road, linear measurement, background
29	RDLB	road, linear measurement, foreground
30	RDLM	road, linear measurement, middle ground
31	RDLV	road, linear measurement, very distant
32	RF	rocks, foreground
33	RGB	range grass, background
34	RGF	range grass, foreground
35	RGM	range grass, middle ground
36	RGV	range grass, very distant
37	RM	rocks, middle ground
38	RMB	rolling mountains, background
39	RMF	rolling mountains, foreground
40	RMM	rolling mountains, middle ground

Table 8 (cont'd)

NO.	CODE	DESCRIPTION
41	RMV	rolling mountains, very distant
42	SBB	scrub brush, background
43	SBF	scrub brush, foreground
44	SBM	scrub brush, middle ground
45	SBV	scrub brush, very distant
46	SK	sky
47	SMB	sharp mountaintops, background
48	SMF	sharp mountaintops, foreground
49	SMM	sharp mountaintops, middle ground
50	SMV	sharp mountaintops, very distant
51	SNB	snow, background
52	SNF	snow, foreground
53	SNM	snow, middle ground
54	SNV	snow, very distant
55	STAB	structured man's influence area, background
56	STAF	structured man's influence area, foreground
57	STAM	structured man's influence area, middle ground
58	STAV	structured man's influence area, very distant
59	STLB	structured man's influence linear, background
60	STLF	structured man's influence linear, foreground
61	STLM	structured man's influence linear, middle ground
62	STLV	structured man's influence linear, very distant
63	SWB	still water, background
64	SWF	still water, foreground
65	SWM	still water, middle ground
66	SWV	still water, very distant
67	TB	trees, background
68	TF	trees, foreground
69	TFB	flat topography, background
70	TFF	flat topography, foreground
71	TFM	flat topography, middle ground
72	TFV	flat topography, very distant
73	TFB	tall grass, background
74	TGF	tall grass, foreground
75	TFM	tall grass, middle ground
76	THB	hill topography, background
77	THF	hill topography, foreground
78	THM	hill topography, middle ground
79	THV	hill topography, very distant
80	TIB	indeterminant topography, background
81	TIF	indeterminant topography, foreground
82	TIM	indeterminant topography, middle ground
83	TIV	indeterminant topography, very distant
84	TM	trees, middle ground
85	TRB	rolling topography, background

Table 8 (cont'd)

86	TRF	rolling topography, foreground
87	TRM	rolling topography, middle ground
88	TRV	rolling topography, very distant
89	TSB	sloped topography, background
90	TSF	sloped topography, foreground
91	TSM	sloped topography, middle ground
92	TSV	sloped topography, very distant
93	TV	trees, very distant

Definitions

ZONE	DEFINITION
range grass, foreground	The grasslands need not be dense and generally will be fairly sparse (i.e., clumps separated by earth) length less than one foot. Color: brown through green.
range grass, middle ground	Same as above but middleground.
tall grass, foreground	Very thick and dense grasses with length greater than one foot. Emphasis, here, is on thickness, not height. Generally some shade of green.
tall grass, middle ground	Same as tall grass foreground, but middleground.
grasses, very distant	Any *grasslike* thing in very distant. No details visible, including details about terrain. Different from Very Distant Trees only by color.
grasses, background	Any grass in the background.
trees, foreground	Treelike, i.e. height greater than crown width with some sort of trunk or central stem.
trees, middle ground	Same as above, but middleground.
trees, background	Same as above but background.
trees, very distant	Same as above but very distant.
scrub brush, foreground	Something not fitting into the description of tall grass, range grass or trees foreground. Can be shrubs, garden plants, vines, etc.

Table 8 (cont'd)

ZONE	DEFINITION
scrub brush, middle ground	Same as above.
above tree line, all distances	A place devoid of vegetation due to altitude. Tree line should be visible in order to make this judgment. Similar to Rock in foreground and middle ground.
rocks, all distances	Must be large enough to see at least 3 sides. Can be the side of a hill or a patch of rocks on a hillside. Generally only in foreground and middle ground. Exclusive of above tree line.
bare soil, all distances	Places devoid of living matter. This is exclusive of rocks. That is, the area can contain soil and rocks smaller than 7 inches.
blacktop MPB damage, all distances	Greater than 50 percent of individual trees denuded.
evidence of MPB damage, all distances	Applies only in foreground and middle ground -- that portion of a tree that was partially reddish in color (up to about 1/3 reddish).
redtop MPB damage, all distances	The entire tree or group of trees exhibiting more than 1/3 reddish foliage.
topography, flat, all distances	Apparent changes in deviation are minor relative to adjacent areas. (What appears flat, and is recorded as flat, in the background and very distant might be coded as rolling if it occurred in the foreground.)
topography, hill, all distances	Relatively elevated land mass with a prominent top or peak that dominates the foreground and middleground, is more or less dominant in the background (less dominant in observer superior cases, more dominant in observer inferior), and generally insignificant in very distant.
topography, rolling, all distances	Hilly topography not dominated by any particular hill or peak.

Table 8 (cont'd)

ZONE	DEFINITION
topography, rolling mountains, all distances	Significantly elevated land masses that dominate the background and very distant, but that are not included in the sharp mountain category.
topography, sharp mountains, all distances	Significantly elevated land mass dominating the background or very distant and characterized by un-vegetated tops, or vegetated tops having angular ridges or rocky protrusions.
topography, slope, all-distances	Non-undulating or gently undulating inclined area with no dominating top or peak.
topography, indeterminant, all distances	Areas where the type of topography is not discernible. Places where the *lay of the land* cannot be seen due to vegetation blocking the view.
still water, all distances	Water features lacking both linear orientation and evidence of flow.
moving water, all distances	Water features characterized by linear orientation or evidence of flow.
roadlike features, all distances	Manmade features oriented towards travel or transportation (roads, trails, railroads, etc.). Two measurement categories were employed: (1) linear (code prefix RDL) -- length of lines measured on features too narrow to register on area when digitizing and (2) area (code prefix RDA) -- area of features as normally coded.
structural features, all distances	Any non-roadlike evidence of man's influence (fences, houses, towns, etc.). Two measurement categories were employed: (1) linear (code prefix STL) -- length of lines measured on features too narrow to register an area when digitized (2) area (code prefix STA) -- area of features as normally coded.

Table 8 (cont'd)

ZONE	DEFINITION
sky	Any part of the scene that is above the horizon (includes clouds and blue sky).
clouds	Area in clouds.
snow, all distances	Snow.

In order to maintain degrees of freedom, the SBE scores for a pooled group of 367 observers for all 60 photos was used as the dependent (Y) variable. This was justified by the fact that the SBE and LCJ metric derivations were identical for the 16 common photos.

A series of procedures including correlation analysis, XY scatter-plots, and approximately 3000 "best" regression models produced a candidate set of independent variables which included:

1. Area in Sharp Peaked Mountains across all distance classes (SHRP)
2. Area in background and very distant forest (BVF)
3. Area in flat topography in the foreground, middleground and background. This is an index of how expansive a more distant view is. (FLT)
4. Are in hilly and/or sloping terrain in the foreground and middleground. This is an index of obstruction of distant views. (HILL)
5. Ratio of area in bare (non-vegetated) ground and rocks in the foreground, middleground, and background to the area in foreground, middleground, and background forest. This is a forest density variable. (FORDEN)
6. Area in insect damage in the middleground which includes all faders, red top and black top damage. (MDAM)

All variables are correlated with the preference metric and are not intercorrelated above the r = 0.40 level. These independent variable indices were determined a-priori with the aid of many individuals. In other words, it was felt that these kinds of landscape features would be important predictors of scenic preference for vistas.

Eighteen different indices of insect damage were tried in the modeling routines. Initially, only middleground damage correlated with scenic preference based upon tests of H_o: $r \neq 0$. Indices included combinations of red and black top damage for each distance zone and combinations of zones as well as ratios of damaged crowns to undamaged forest area.

The following candidate models and associated statistics of predictive reliability were estimated for regressions for SBE scores for naive observers on the independent variables noted above for 64 landscapes[1] (Table 9). All models were computed using a General Linear Models algorithm in SPS V3.0 (Buhyoff et al. 1980).

The table indicates that several good predictive models are available for naive observers. Specifically models 1, 2, 4, 11, 12 and 13 are good candidates for empirical fits. The choices are based upon examination of the equation standard error, F ratio, R^2, Mallows' C_p Statistic[2] and PRESS statistic. Specifically, the cumulative PRESS statistic is useful for obtaining an estimate of predictive precision. The PRESS is the cumulative residual total based upon estimating the model N times. Each individual PRESS is the residual for the ith case when vector B is estimated without the ith case (Allen 1974).

All coefficient estimate signs are the same across all models and are intuitively appealing. Also, similar coefficient estimates have similar values across all models. The stability of the coefficients was assessed by both adding and deleting variables to all models and by changing variable values. Coefficient estimate signs and magnitude did not fluctuate. No collinearity problems, apparently exist.[3] This was also evident at a more intuitive level in that no correlations were above 0.40.

---

[1] Two outliers were dropped because of significant t-tests for outlier values. Upon inspection of these landscapes, it was noted that they were both quite unusual and were very different in terms of photographic quality and composition. These landscapes should not have been included in the first place.

[2] Mallows' C_p statistic is based on the variance of the estimates and the bias of the estimates. Good prediction models will have very small or negative C_p-P values where P = the number of predictors in the model (Weisberg 1980).

[3] The condition number of the independent variable matrix was, on the average, less than .05 of one percent of the collinearity number.

TABLE 9

Candidate Scenic Vista Regression Models

MODEL #	VARIABLES								STATISTICS OF FIT AND PREDICTION				
	FORDEN	MDAM[a/]	SHRP	SHRP2	FLT	BVF	LBVF	HILL	S.E.	C_p	F [d/]	R^2	PRESS
1	(.02)$_-$	(.04)$_-$	[b/](.0001)$_+$ [c/]	(.0001)$_-$	(.004)$_+$	(.01)$_+$			32.13	6.50	11.52	0.55	68,210
2	(.07)$_-$	(.04)$_-$	(.0001)$_+$	(.0004)$_-$		(.10)$_+$		(.18)$_-$	33.45	13.56	9.55	0.52	83,343
3	(.006)$_-$	(.03)$_-$	(.0001)$_+$	(.0001)$_-$	(.01)$_+$				33.00	10.95	11.87	0.52	77,197
4		(.12)$_-$	(.0001)$_+$	(.0001)$_-$	(.002)$_+$	(.003)$_+$			32.71	9.88	12.28	0.53	71,603
5	(.13)$_-$	(.06)$_-$	(.0001)$_+$	(.0004)$_-$			(.18)$_+$		34.43	16.23	10.01	0.48	89,368
6	(.01)$_-$	(.06)$_-$	(.0001)$_+$	(.0004)$_-$		(.04)$_+$			33.70	13.50	10.93	0.50	77,987
7		(.10)$_-$	(.0001)$_+$	(.0004)$_-$		(.07)$_+$		(.03)$_-$	34.20	15.38	10.29	0.48	77,021
8	(.30)$_-$		(.0001)$_+$	(.0001)$_-$	(.002)$_+$	(.10)$_+$	(.38)$_+$		32.07	8.57	11.18	0.55	70,637
9	(.27)$_-$	(.09)$_-$	(.0001)$_+$	(.0001)$_-$	(.006)$_+$		(.08)$_+$		32.36	9.59	10.82	0.55	80,472
10		(.12)$_-$	(.0001)$_+$	(.0001)$_-$	(.002)$_+$	(.004)$_+$			32.77	8.93	12.45	0.53	72,986
11		(.15)$_-$	(.0001)$_+$	(.0001)$_-$	(.002)$_+$	(.16)$_+$	(.07)$_+$		32.11	7.60	11.35	0.55	71,769
12		(.15)$_-$	(.0001)$_+$	(.0001)$_-$	(.003)$_+$		(.002)$_+$		32.38	7.58	13.00	0.54	72,569
13		(.10)$_-$	(.0001)$_+$	(.0001)$_-$	(.04)$_+$			(.02)$_-$	33.71	12.37	11.14	0.50	78,236
14			(.0001)$_+$	(.0001)$_-$	(.009)$_+$	(.02)$_+$		(.16)$_-$	32.58	8.29	12.71	0.53	73,693
15			(.0001)$_+$	(.0001)$_-$	(.007)$_+$	(.23)$_+$	(.11)$_+$	(.32)$_-$	32.12	7.99	11.34	0.55	70,412

[a/] test of $\beta_{MDAM} = 0$ is one sided, other estimate tests are two tailed.

[b/] attained significance level of $\beta_i \neq 0$.

[c/] sign of coefficient

[d/] All equations are significant at $p \leq .001$, $F(6,57)$.

The overall best model for naive observers (model 1 from Table 9) is represented below:

NAIVE OBSERVERS

$$SBE = 127.12 + 10.32SHRP - 0.57SHRP^2 + 1.79\ BVF - 6.77\ MDAM - 61.07FORDEN + 0.93FLT$$

Preference is a quadratic function of the area in sharp peaked mountains and has a large effect on preference. The greater the area of background and distant forest has a positive effect. Middle ground insect damage has a negative effect as does less dense forest as symbolized by the large negative FORDEN coefficient. Finally, flat topography in the foreground, middleground and background have a positive effect.

Model 1 utilizes independent measures based on square inches. Thus, for example, SHRP is the area in square inches of sharp peaked mountains. Therefore, this model is based upon variable values which do not relate to a measure of overall scene size. For this reason, the independent variables were transformed to proportions of the total vista area by dividing each variable, except FORDEN, by 73.5 square inches (the size of the image from which the digitized areas were taken). FORDEN was not transformed since it is already the ratio of nonforest area to forested area.

Model 1 was recomputed using these new values and yielded the equation:

$$SBE = 127.12 + 759.17\ \%SHRP - 3055.18\ \%\ SHRP^2 + 131.51\ \%BVF - 497.79\ \%MDAM - 61.07\ FORDEN + 68.53\ \%FLT$$

This model is significant at $p \leq .0001$ ($F_{6,57} = 11.52$) with an $R^2 = 0.55$. All coefficients are significant at $p \leq .05$, the cumulative PRESS = 71671 and the S.E. of the equation = 32.13. Equation 2 expressed in standardized (Z) form where the intercept is zero is:

$$Z_{SBE} = 1.27\ \%SHRP - 1.18\ \%SHRP^2 + 0.28\ \%BVF - 0.18\ \%MDAM - 0.21\ FORDEN + 0.28\ \%FLT$$

The standardization is necessitated since FORDEN was not divided by 73.5 square inches. Thus coefficient bases are different in their raw form. This standardized equation shows that sharp mountains accounts for the largest amount of variance in visual preference for vistas and that Mountain Pine Beetle damage in the middleground accounts for the least. The other variables are approximately equivalent in their predictive importance in this model.

In summary, insect damage has a slight damping effect on scenic preference when it occurs in the middleground. If such damage is present in vistas with either or any combination of a long unobstructed scenic view of dense forests leading toward a backdrop of sharp peaked mountains, then the damage effect becomes smaller. It is possible that the rest of the landscape can overpower any effect damage might have. This is especially true in the case where sharp terrain dominates the landscape. Note, however, that increasing area in sharp mountains will increase visual preference only to a point (approximately 20 percent of the total vista area) past which preference will begin to decline.

Buhyoff and Leuschner (1978) and Buhyoff et al. (1980) found a difference in the regression equations which predicted visual preference for Southern Pine Beetle (SPB) damaged landscapes between naive and informed observers. Basically, SPB damage was found to have a more pronounced effect on the visual preference of those observers who knew they were seeing effects of insect damage. For this reason, the hypothesis that there would not be differences between the naive and informed observers in this study was tested by comparing similar regression model forms across these two groups of observers.

Model 1 from above was computed for the group of informed observers and the following resulted:

INFORMED OBSERVERS

$$SBE = 87.58 + 7.94SHRP - 0.39SHRP^2 + 2.27BVF - 11.13MDAM$$
$$-45.86FORDEN + 0.99FLT$$

All coefficients were significantly different from zero at $p \leq .05$ (two tailed). The equation is also significant at $p \leq .0001$ ($F_{6,57} = 12.20$). The R^2 for the model is 0.56. Note that the signs of the coefficients are the same and also the similarity in estimates between the naive (equation 1) and informed observer models. However, tests for the equivalence of the coefficients between models 1 and 2 indicate that the models are not significantly different and could be pooled into one comprehensive equation if that were desirable.

While models 1 and 4 were not different, the possibility of another MPB damage variable (other than MDAM) being a more important predictor for informed observers was investigated. Since much of the black top and fader damage cannot be perceived readily or clearly in large vista scenes, percent of vista area in redtop damage (all distance classes) (TRED) was selected and substituted for MDAM in the above model and all other variables (except FORDEN) were used in their "proportion of vista area" transform. However, this model was not significant due to an insignificant coefficient estimate for FORDEN. This last variable was dropped and yielded the resulting equation:

$$SBE = 33.03 + 632.5\ \%SHRP - 2189.68\ \%SHRP^2 + 186.21\ \%BVF +$$
$$77.77\ \%FLT - 583.02\ \%TRED$$

This model is significant at $p \leq .0001$ ($F_{5,58} = 14.55$). The R^2 for the model is 0.55, the S.E. of the equation is 33.54, the PRESS = 81976.43, and all coefficient estimates are significant at $p \leq .0001$.

The standardized (Z) form of equation 5 is:

$$z_{SBE} = 0.99\ \%SHRP - 0.79\ \%SHRP^2 + 0.37\ \%BVF + 0.30\ \%FLT - 0.28\ \%TRED \quad (6)$$

The results are similar to those discussed above in that percent area in sharp mountains again accounts for the most variance in visual preference and MPB damage the least. However, the relative importance of all variables except %SHRP is about the same in this model. In other words, informed observers seem to be more sensitive to the sum of redtop damage than they do MDAM. The comparison is not completely fair since different variable subsets are used as predictors in models 4 and 6. However, a better test of this increased sensitivity to redtop damage by informed observers comes in the test of equivalence between Model 5 and the identical model form for naive observers. In fact when the visual preferences of naive observers were regressed on the independent variables expressed in 5, a significant ($p < .0001$) equation resulted but the coefficient estimate for %TRED was not significantly different from zero ($p = 0.53$). All other coefficients (%SHRP, $\%SHRP^2$, %BVF and %FLT) are significant at $p < .001$. Therefore, informed observers are keying on redtop damage and it has a negative visual impact. On the other hand, for naive observers, redtop damage is not accounting for any significant variation in preference.

Model 2 likely represents a good predictive model for naive observers who might be represented by tourists and nonresidents of the Front Range. On the other hand, Model 5 is probably a better predictive model to use for residents of the Front Range and/or other populations or forest user subgroups known or thought to be sensitized to MPB damage effects.

Overall, Mountain Pine Beetle damage has a negative scenic impact. Negative impact is greatest on vistas which are characterized by little topographic variability, areas of restricted or narrow view of more distant

features and sparsely forested areas. On the other hand, MPB damage seems to have more of a slight dampening effect on vistas which offer long and wide views across dense forest lands of high ridges, peaks or ranges.

Model Development: Near-View

A total of 195 "inventory plots" were established in the Colorado Front Range in the summers of 1979 and 1980[4]. Each plot was approximately one acre in size, and plots were chosen to represent a wide range of overstory, understory, and insect damage and management conditions in the Front Range. At each plot four color-slide photos were taken along with an intensive forest inventory. Slope and aspect of each plot was measured and recorded at the plot center. Trees (including seedlings and saplings), ground cover, downed wood and slash, stumps and ground disturbance were measured and recorded for every plot. Standard forest mensuration procedures were used in each case. Status of insect damage for both MPB and WSB was assessed and recorded for relevant tree species. All field inventory data was converted to a per-acre unit basis for each plot.

The inventory procedure for each sample plot is summarized in Figure 4. Orientation of the plot was determined by the first photo sample direction which was determined by a randomly selected compass heading (1-360). Other coordinates of the plot were established at 90° intervals (orientation 1 + 90°, 180°, 270°). A color slide was taken at eye-level along each of the four coordinates. Two classes of seedings (0 to 2 feet height, 2 to 3.9 feet height) and saplings (4.0 feet to 4.9"DBH) were counted within the 1/100th acre plot (11.8' radius circle). Seedlings and saplings were classified as to species and insect damage. Timber greater than 5" DBH was tal-

[4] Of the 195, 75 plots were established under the separate "Boulder Canyon Vegetative Management Scenic Assessment" project, Terry C. Daniel principle investigator. Costs for establishment and maintenance of the plots were covered by that project agreement.

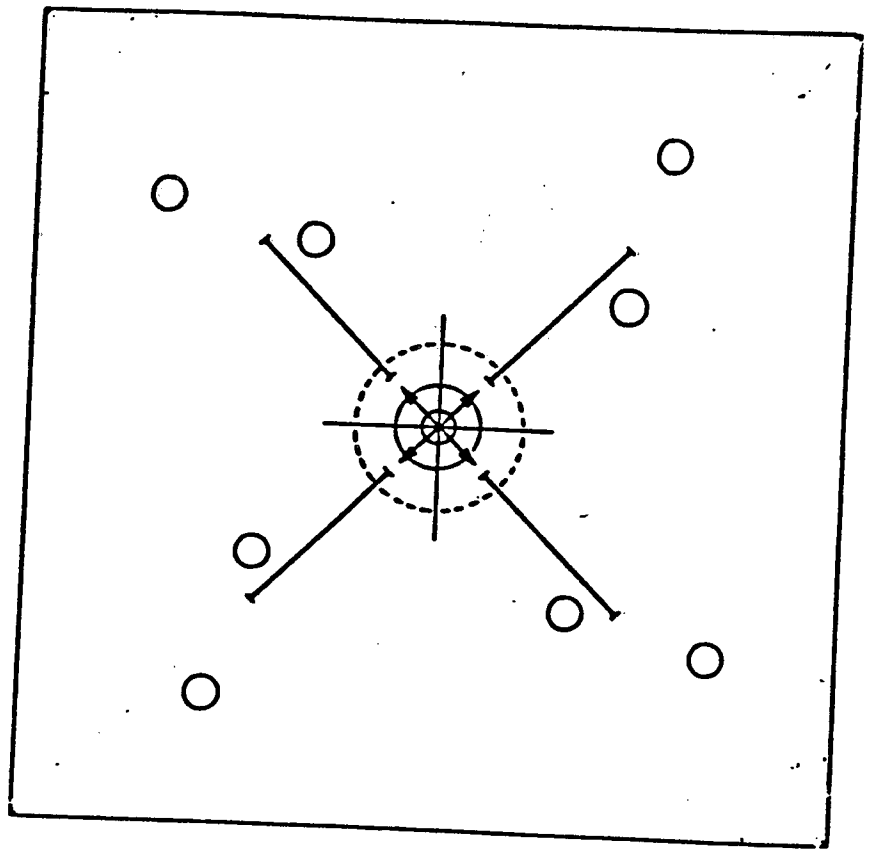


Figure 4. Schematic of inventory plot procedure for Near View model development.

lied in diameter classes (5" - 8.9", 9" - 11.9", 12" - 15.9", 16" - 19.9", 20" - 23.9", 24" - 27.9", > 28" using a variable plot, 10 BAF sampling procedure. Trees were classified as to species and insect damage (MPB = no damage, green fader, brown-orange > 50% needle, brown-orange < 50% needles, black/small twigs remain, black/major branches remain, dead snag; WSB = no damage, one-year, two-year, top-kill < 3', top-kill > 3', dead). Ground cover was sampled using 9 square foot plots at 8 locations. Wet weight (grms) of grasses, ferns, and shrubs was estimated for each plot and one plot (at random) was clipped and weighed after all 8 had been estimated. Other measures, such as height and canapy of ground covers and percent of ground cover were also recorded. Downed wood was inventoried using 50 foot linear transects according to procedures described in Brown (1974). Downed wood categories included small materials (0 - .25", .25" - 1.0", 1.0" - 3.0" diameter) and individually recorded materials greater than 3.0" diameter. Larger materials were classified as sound or rotten, and as either natural or slash. Fuel depth was also measured at three locations on the transect. Stumps (< 5", 5 - 9", 9 - 12", 12 - 16", 16 - 20", > 20") were tallied within a 1/10th acre plot (37' radius circle) along with estimates of the area of any mechanical disturbance.

All physical data was input to a system of computer programs that convert plot tallies into per-acre values and aggregate values into an integrated file for each plot. These data are presented in appendix A of this report. Physical data files were merged with SBE files. SBEs were based on observer judgements of the four slides at each plot. These data files formed the basis for Scenic Beauty Prediction Models for in-forest views.

Four color slides were available to represent the visual characteristics of each sample plot. When 1979 and 1980 plot samples were combined 780 color slides were available for study. An additional 150 plots (600 slides) from

1979 were re-photo sampled in 1980, but not reinventoried. The photos were not included in model development studies. Each of the principle plot slides was presented to panels of from 25 to 35 college student observers who independently rated the scenic beauty of the area represented by each slide. Because each panel judges only about 100 of the inventory plot slides, 8 different panels were required to obtain judgments for all of the slides.

To insure comparability of judgments from the different panels, 25 "baseline" slides were randomly interspersed among the inventory plot slides shown to each panel. These baseline slides were identical for each panel and served to anchor the SBE scale to a common origin; by definition, the average SBE value for the 25 baseline slides is 0 for every panel. The 25 baseline slides were sampled from ponderosa pine forest areas in the Coconino National Forest, Arizona. They have served as the zero point or anchor scenes in a number of previous scenic beauty assessment studies (e.g., Daniel, et al., 1977; Schroeder & Daniel, 1980; Schroeder & Daniel, 1981) and in the scenic assessments in the preceding sections of this report. Thus, each of the 8 panels saw a randomly selected and randomly ordered set of 100 slides from the Colorado Front Range inventory plot sample, along with a constant set of 25 baseline slides.

Intercorrelations among the panels on the 25 baseline slides ranged from .89 to .93 averaging .90. Consistent with previous research, these correlations are typically high and indicated generally good agreement among this sample of observers as to the perceived scenic beauty of the sites represented. Data from all panels, then, were combined to provide SBE values for each of the four photosamples at each inventory plot. Individual slide SBEs were averaged to yield a scenic beauty value for each plot.

Physical feature data for each plot were subjected to a number of

analytic procedures, including simple and partial correlation and factor analysis, to determine interrelationships among variables. This procedure guided the collection of individual variables into composite variables (e.g., ponderosa pine 5-9 and 9-12 inches DBH were combined to form one "medium pines" variable; downed wood categories 0 to .25, .25 to 1.0 and 1.0 to 3.0 inches diameter were combined to form "downed wood less than 3 inches"). The objective was to establish a large, but manageable set of candidate independent variables for a multiple regression analysis. For this purpose, large numbers of highly intercorrelated variables are undesirable. The final set of candidate variables is listed in Table 10.

Each of the 195 inventory plots provided a single case for the development of the scenic beauty prediction models. The four SBE values from each plot were averaged to provide the dependent variable, and the associated values for the physical features of each plot formed the set of independent variables. This variable set was subjected to a number of different multiple regression analyses specifying different subsets of the independent variables, different orderings of the variables, and selecting different subsets of the plots for separate analyses. For each analysis, some of the inventory plots were withheld from the model development to provide a direct assessment of the predictive validity of resulting regression equations. For example, for the "0 percent or greater ponderosa pine" model, applicable to all 195 plots, 49 plots were withheld leaving 146 cases for developing the model.

The criteria for selection of models (there are always a number of possible models when so many independent variables are available) were of two types, statistical and practical. The three models presented in Tables 11, 12, and 13 are all statistically reliable at conventional significance levels,

Table 10

Independent Variable Set Used for Developing
In-Forest View Scenic Beauty Prediction Models

Variables	Unit
Ponderosa Pine seedlings	Trees/acre
Ponderosa Pine saplings	Trees/acre
Ponderosa Pine 5-12" DBH	Trees/acre
Ponderosa Pine 12-20" DBH	Trees/acre
Ponderosa Pine > 20" DBH	Trees/acre
Douglas Fir seedlings	Trees/acre
Douglas Fir saplings	Trees/acre
Douglas Fir 5-20" DBH	Trees/acre
Douglas Fir > 20" DBH	Trees/acre
Oaks	Trees/acre
Aspen	Trees/acre
Limber Pine	Trees/acre
Juniper	Trees/acre
Spruce	Trees/acre
Lodgepole Pine	Trees/acre
Proportion of Ponderosa Pine which are Green Faders	0 - 1.0
Proportion of Ponderosa Pine which are Brown/Orange	0 - 1.0
Proportion of Ponderosa Pine which are Gray/Black (no needles)	0 - 1.0
Gras	Pounds/acre
Forbs	Pounds/acre
Shrubs	Pounds/acre
Downed wood less than 3 inches in diameter	Cubic ft./acre
Downed wood greater than 3 inches and sound	Cubic ft./acre
Downed wood greater than 3 inches and rotten	Cubic ft./acre

Table 11. Colorado Mountain Pine Beetle MOdel for plots with greater than 0 percent ponderosa pine

Step	Variable	Mean	S.D.	B	Beta	R
1	Downed wood greater than 3", sound: cu. ft./acre	68.19	239.39	-.043	-.274	.356
2	Grass: lbs/acre	105.89	104.78	.104	.294	.454
3	Shrubs: lbs/acre	310.84	447.55	.023	.274	.536
4	Douglas Fir Saplings: Trees/acre	55.69	132.84	-.057	-.206	.562
5	Ponderosa Pine: 5"-12" DBH: Trees/acre	161.88	225.46	-.028	-.171	.593
6	Proportion of Ponderosa Pine which are Brown/Orange (MPB)	.11	.21	-36.512	-.208	.615
7	Juniper: Trees/acre	3.60	16.63	.290	.130	.631
8	Spruce: Trees/acre	.62	5.32	.727	.104	.646
9	Ponderosa Pine: 12"-20" DBH: Trees/acre	35.63	33.78	.258	.235	.656
10	Aspen: Trees/acre	158.58	491.50	.009	.115	.667
11	Proportion of Ponderosa Pine which have no needles (MPB)	.06	.14	-40.349	-.157	.675
12	Oak: Trees/acre	477.40	1427.77	-.003	-.103	.682

Number of plots: 146

Table 12. Colorado Mountain Pine Beetle Model for plots with greater than 40 percent ponderosa pine.

Step	Variable	Mean	S.D.	B	Beta	R
1	Downed wood less than 3": cu. ft./acre	285.89	170.54	-.039	-.167	.407
2	Grass: lbs/acre	100.26	100.42	.095	.242	.547
3	Downed wood greater than 3", sound: cu. ft./acre	83.26	283.26	-.051	-.369	.589
4	Juniper: Trees/acre	1.94	11.18	.886	.252	.616
5	Ponderosa Pine: 5"-12" DBH: Trees/acre	198.64	265.57	-.054	-.363	.641
6	Spruce: Trees/acre	.47	4.54	2.407	.277	.686
7	Ponderose Pine: 12"-20" DBH: Trees/acre	36.40	33.54	.204	.174	.696
8	Proportion of Ponderosa Pine which are Brown/Orange (MPB)	.09	.18	-30.996	-.146	.707
9	Oak: Trees/acre	.95	9.07	-.451	-.104	.715
10	Proportion of Ponderosa Pine which have no needles (MPB)	.06	.14	-52.566	-.189	.721
11	Shrubs: lbs/acre	195.98	297.20	.015	.116	.729
12	Forbs: lbs/acre	158.78	148.68	.030	.112	.737

Number of plots: 92

Table 13. Colorado Mountain Pine Beetle Model for plots with greater than 80 percent ponderosa pine.

Step	Variable	Mean	S.D.	B	Beta	R
1	Downed wood less than 3": cu. ft./acre	291.32	174.56	-.062	-.267	.401
2	Grass: lbs/acre	109.94	107.45	.086	.227	.550
3	Ponderosa Pine: 12"-20" DBH: Trees/acre	33.38	32.51	.207	.166	.583
4	Proportion of Ponderosa Pine which have no needles (MPB)	.05	.11	-73.037	-.205	.631
5	Downed wood greater than 3", rotten: cu. ft./acre	182.50	242.73	.020	.118	.659
6	Douglas Fir Saplings: Trees/ acre	5.96	24.37	-.204	-.123	.673
7	Proportion of Ponderosa Pine which are Brown/Orange (MPB)	.10	.20	-30.207	-.151	.684
8	Oak: Trees/acre	1.19	10.18	-.452	-.113	.694
9	Juniper: Trees/acre	1.84	11.54	.786	.223	.702
10	Downed wood greater than 3", sound: cu.ft./acre	69.53	225.96	-.029	-.159	.713
11	Forbs: lbs/acre	169.75	150.26	.027	.101	.724
12	Ponderosa Pine: 5"-12" DBH: Trees/acre	217.54	286.90	-.060	-.422	.732

Number of cases: 73

and each accounts for between 46 and 55 percent of the variance (R^2) in perceived scenic beauty. Of equal importance, however, is that all three of the models have substantial utility for predicting the scenic consequences of MPB damage and insect-targeted vegetative management alternatives.

The "0 percent or greater ponderosa pine" model is applicable to all of the sample plots in the Front Range. This model, then, appears to have greater generality, but this is achieved at the expense of some precision. With 12 variables in the model, just less than 50 percent of the variance in SBE values is explained; multiple R = .68 (R^2 = .46).

Several features of this model are noteworthy. First, as with similar models for ponderosa pine forests (Schroeder & Daniel, 1981) large ponderosas (12 - 20 inches DBH) and lush ground covers (grasses and shrubs) are substantial positive scenic features. Downed wood and pole size ponderosa pines have negative scenic effects. MPB damage, represented by two categories, brown-orange and gray-black (needles dropped) killed trees, both contribute negative scenic effects. The presence of other tree species was generally a positive scenic feature, with the exception of douglas fir saplings and oaks. Both of these species may be found to flourish in ponderosa pine stands that have experienced heavy MPB mortality in past years.

The second model was restricted to a less diverse set of sample plots, those having "40 percent or more ponderosa pine." Based on this criterion, 112 plots were available for model development, with 20 of those reserved for subsequent predictive validity tests. The remaining 92 plots served as the basis for the model presented in the table. Again, large ponderosas and lush ground covers were positive scenic elements, and downed wood and pole size ponderosas were negative elements. Both brown-orange and gray-black MPB damage were negative scenic features. Other tree species, except for oak, were positive scenic elements.

The 40 percent model, while somewhat more restrictive, was more powerful statistically than was the unrestricted model. With 12 independent variables, 54 percent of the variance in SBEs could be explained. Some of this gain is an artifact of reducing the number of cases in the model.

The most restricted model, including only plots having 80 percent or more ponderosa pine, is based on a total of 90 plots with 17 of those reserved for subsequent model tests. The model based on the remaining 73 plots has many features in common with the first two models presented. Large ponderosas and lush ground covers produce positive effects while downed wood and pole size ponderosas are negative. Brown-orange and gray-black MPB damage are also negative scenic features. The presence of juniper trees on the plots was positive, while oak and douglas fir saplings made negative contributions to perceived scenic beauty.

Rotten downed wood greater than 3 inches in diameter entered this model as a positive variable. This is in contrast to the substantial negative effects of solid (newer) downed wood in all size classes. Rotten logs and other downed wood may have positive scenic value in its own right, but more likely it is other site characteristics associated with rotten downed wood that accounts for most of the positive effect. Larger volumes of rotten downed wood would indicate a site where tree mortality and/or management produced slash is old and decayed, and where regrowth of overstory and understory has advanced. This may be compared to sites where downed wood is newer and solid, and the effects of the mortality or management are still visible.

In combination the Near-View models are highly consistent and intuitively very reasonable. The implications of these models for MPB management are straightforward and important. Clearly, the MPB has direct negative scenic impacts--all models found brown-orange and gray-black damage to have

to have significant negative effects on perceived scenic beauty. Moreover, the secondary effects of MPB mortality, downed wood and the intrusion of competing tree species, such as douglas fir and oak, are also negative. The primary targets of MPB (large mature ponderosa pines) are among the most important positive scenic features in the Front Range plots. Thus, the negative scenic impacts of MPB are substantial, providing one incentive for management action targeted on controlling this pest.

It should also be noted that many of the effects of MPB-targeted management actions may, themselves, have negative scenic consequences. Management actions that remove large ponderosa pines, produce large volumes of downed wood and slash, and disturb ground covers can be expected to degrade scenic values. The models clearly indicate that open stands of mature ponderosa pine with little or no downed wood and with vigorous ground covers of grasses, forbs, and shrubs should, for scenic purposes, be the goal of vegetative management in the Front Range. Whether these scenic goals are compatible with insect control, timber production, and other social and economic objectives should be carefully considered in the context of the comprehensive Pest Management Program.

References

Allen, D. M. The relationship between variable selection and prediction. Technometrics. 1974, 16, 125-127.

Arthur, L. M. Predicting scenic beauty of forest environments: Some empirical tests. Forest Science. 1977, 23, 151-159.

Arthur, L. M., Daniel, T. C., & Boster, R. M. Scenic assessment: An overview. Landscape Planning. 1977, 4, 109-129.

Brown, J. K. Handbook for Inventorying Downed Woody Material. USDA Forest Service General Technical Report INT-16, Ogden, Utah: Intermountain Forest and Range Experiment Station, 1974.

Buhyoff, A. J., & Leuschner, W. A. Estimating psychological disutility from damaged forest stands. Forest Science. 1978, 24, 424-432.

uhyoff, A. J., Leuschner, W. A., & Arndt. Replication of a scenic preference function. Forest Science. 1980, 26, 227-230.

Buhyoff, A. J., & Wellman, J. D. The specification of a non-linear psychophysical function for visual landscape dimensions. Journal of Leisure Research. 1980, 12, 257-272.

Buhyoff, A. J., Wellman, J. D., Harvey, H., & Fraser, R. A. Landscape architects' interpretations of peoples' landscape preferences. Journal of Environmental Management. 1978, 6, 255-262.

Buhyoff, A. J., & Riesenman, M. F. Manipulation of dimensionality in landscape preference judgments: A quantitative validation. Leisure Sciences. 1979, 2, 221-238.

Daniel, T. C., Anderson, L. M., Schroeder, H. W., & Wheeler, T. W. III. Mapping the scenic beauty of forest landscapes. Leisure Sciences. 1977, 1, 35-52.

aniel, T. C., & Boster, R. S. Measuring Landscape Aesthetics: The Scenic Beauty Estimation Method. USDA Forest Service Research Paper RM-167, Fort Collins, Colorado: Rocky Mountain Forest and Range Experiment Station, 1976.

Daniel, T. C., & Schroeder, H. W. Scenic beauty estimation: Predicting perceived beauty of forest landscapes. Proceedings of Our National Landscape. Berkeley, California: Pacific Southwest Forest and Range Experiment Station, 1979.

Daniel, T. C., Wheeler, L., Boster, R. S., & Best, P. Quantitative evaluation of landscapes: An application of signal detection analysis to forest management alternatives. Man-Environment Systems. 1973, 3, 330-344.

Guilford, J. P. Psychometric methods. New York: McGraw-Hill, 1954.

Jackson, R. H., Hudman, L. E., & England, J. E. Assessment of the environmental impact of high voltage power transmission lines. Journal of Environmental Management. 1978, 6, 153-170.

Shafer, E. L., Hamilton, J. F., & Schmidt, E. A. Natural landscape preferences: A predictive model. Journal of Leisure Research. 1969, 1, 1-19.

Schroeder, H. W., & Daniel, T. C. Predicting the scenic quality of forest road corridors. Environment and Behavior. 1980, 12, 349-366.

Schroeder, H. W., & Daniel, T. C. Progress in predicitng the perceived scenic beauty of forest landscapes. Forest Science. 1981, 27, 71-80.

Schweitzer, D. L., Ulrich, J. R., & Bensen, R. E. Esthetic evaluation of timber harvesting in the northern Rockies -- A progress report. USDA Forest Service Research Note INT-203, Intermountain Forest and Range Experiment Station, Ogden, Utah, 1976.

Weisberg, S. Applied linear regression. New York: John Wiley and Sons, 1980.